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Electrocardiographic Studies of Free-Swimming Sharks

Abstract. *Electrocardiograms were taken of young lemon sharks,* Negaprion brevirostris, *as they swam freely in a circular concrete pool. Electrodes attached to the fin and torso yielded negligible or minute deflections, but direct leads yielded satisfactory recordings.*

Few accounts of the elasmobranch electrocardiogram are available: Kisch (*1*) has reported epicardial and endocardial tracings from two species of sharks and two species of skates which were anesthetized and submerged in a small tank; Satchell (*2*) studied restrained dogfish. However, up to the present, no one has taken an electrocardiogram of a free-swimming marine animal although King *et al.* (*3*) with difficulty recorded a few beats from the heart of a beluga whale. We have devised a method for the electrocardiography of freely moving sharks in a pool of flowing sea water.

In preliminary experiments we found that electrodes attached to the fin and torso yielded minimal deflections because the shark's heart is so well insulated by its cartilaginous skeleton. Hence direct leads were essential, but they present problems because of the proximity of the heart to the cartilage. Extracardiac structures in the shark have high electrical resistance not found in electrocardiography of the higher vertebrates.

A free-swimming lemon shark (*Negaprion brevirostris*), approximately 1 m long, was anesthetized (*4*) with MS-222 (tricaine-methane-sulfonate), removed from the water, and strapped to a restraining board (*5*). The gills were perfused with fresh sea water. We used an atraumatic electrode with a 20-gauge hypodermic needle in a plastic jacket that extended 2 mm beyond the tip of the needle. The lumen of the plastic tube, distal to the needle, was filled with agar saturated with sea water. A single exploring electrode was placed over the ventricular epicardium through a drill hole in the skin and coracoid cartilage in the midventral line. The flexible conducting cable (Alpha wire No. 26), 3 ft long, was sutured to the skin at two points as it passed around the right side of the shark to the base of the first dorsal fin where it was again securely sutured. The distal end of the cable with an insulated waterproof connector trailed freely from the leading edge of the fin. The shark was then returned to a circular concrete pool, 4 m in diameter and 40 cm deep, where it recovered rapidly. Two hours later the first tracings were recorded. The shark's electrode cable was attached to a longer cable which passed to a swivel 3 m above the center of the pool and thence to a Sanborn Viso-Cardiette at the side of the pool. The indifferent electrode and ground wires were placed in the water near the edge of the pool (*6*). Electrocardiograms were recorded at paper speeds of 25 and 50 mm/sec with standardization recorded for each experiment.

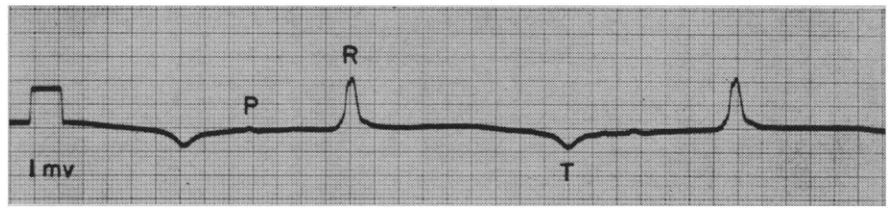

Fig. 1. Representative electrocardiogram of a free-swimming lemon shark (paper speed, 50 mm/sec).

Over a period of 3 years we obtained more than 200 electrocardiographic recordings from 12 lemon sharks about 1 m long and weighing approximately 8 kg. Each shark was studied repeatedly on two or more successive days. A representative electrocardiogram is presented in Fig. 1.

The records made while the shark was resting at the bottom of the pool showed clearly defined waves synchronous with movement of the gills, with a frequency of about half the cardiac rate. However, during active swimming, gill movements were absent since water passed continuously through the open mouth and out the gill slits. Under these circumstances the electrocardiographic deflections appeared with a stable rather than an undulating base line.

The cardiac rate ranged between 30 and 65 beats per minute as the temperature of the water varied. The rate was relatively fixed for a given shark and did not change significantly with various stimuli: tapping the side of the pool, waving the hand, splashing water, or placing dye in the water.

Average measurements in seconds are: P waves, 0.06; P-R interval, 0.38; QRS complex, 0.09; and Q-T interval, 1.04. The ventricular depolarization and repolarization deflections are clearly defined. No attempt is made to analyze magnitude and direction of the deflections because the relationship between the exploring electrode and the heart was not fixed.

We believe that our technique facilitates the study of cardiac function in elasmobranchs and other marine vertebrates under conditions approaching more closely those found in nature than when the animal is restrained, anesthetized, or removed from the water (*7*).

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